Route Guidance Modality for Elder Driver Navigation

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Abstract. Differences in perceptual and cognitive abilities between the young and elderly have implications for in-car tasks. As a primary example, although in-car navigation systems enhance situational awareness, this comes at the cost of increasing visual distraction and cognitive load. To address these shortcomings, this paper explores the efficacy of multi-modal cues for providing route guidance information. We present the results of a study evaluating the impact of multi-modal feedback on driving performance and cognitive load. We found that the full combination of visual, auditory, and haptic feedback was generally most useful to reduce way-finding errors. However, our study highlighted a number of differences between elder and younger drivers for their safer navigation. Adding more modalities strained the already high workload of elder drivers. In contrast, adding haptic feedback to traditional audio and visual feedback led to more attentive driving by younger drivers. Therefore, for elder drivers, navigation systems need to be personalized to enhance the benefit of auditory feedback without increasing the number of sensory feedbacks. For younger drivers, it is necessary to incorporate new non-visual feedback to minimize distractions caused by visual feedback. We demonstrate these results through task performance-based measures, subjective workload measures and through objective workload measures that use psycho-physiological responses of participants to predict a driver’s cognitive load in near real-time.

Keywords: Elderly driver, Car navigation, Cognitive load, Divided attention, Haptics, Psycho-physiological measurement.

1 Introduction

As our society ages, the number of drivers over the age of 65 is rapidly growing. However, the cognitive effects of aging can force them to relinquish control of their cars. Unfortunately, quality of life is acutely linked with the ability to maintain independence in mobility [1, 29]. Thus, reduced mobility combined with the need for mobility independence has substantial negative impact on an individual as well as their family, who often takes on the burden of care [24].

Decay in vision, hearing, and general mobility collectively reduce the performance of elderly drivers (e.g., [10]). Age-related decreases in spatial cognition ability leads to challenges for elderly individuals in accurately forming a mental representation of
a spatial environment and efficiently navigating such environments. For example, it has been found that older adults have difficulty in understanding ‘you-are-here’ maps, which are used to plan simpler driving routes, even though they may increase driving time [30]. In an on-road driving assessment [15], older adults forgot to check blind spots and made errors when asked to report road marking and traffic signs as they drove. In addition, it has been found that older adults are affected more when taking their eyes off of the road, and thus do not use secondary displays in cars as commonly as younger drivers do [18, 20]. These secondary displays, such as in-car navigation systems, typically enhance drivers’ situation awareness, at the cost of increased visual attention and cognitive load. These shortcomings are harder for elderly drivers to overcome; technologies such as GPS systems are often considered too difficult for older drivers to use effectively as a driving aid [20].

We are interested in improving the driving performance of elderly drivers. The relationship between workload and performance is complex. Performance can be affected by workload being too high or too low [27], resulting in a saturation of cognitive capability, the loss of situational awareness or a reduced sense of alertness. Multiple resource theory proposes that the cognitive burden from information overload can be reduced by utilizing multiple modalities to present information [33]. This allows users to process information in parallel rather than sequentially [4].

This paper examines how the usage of multi-modal route guidance cues can lead to safer driving by studying the impact of different combinations of modalities on driving performance for elder and younger drivers.

1.1 Study Overview

The focus of this paper is an investigation of the most effective combinations of feedback modalities for younger and elder drivers’ navigation. We compare driver performance for four different combinations of sensory feedback: 1) visual plus auditory, 2) visual plus haptic, 3) auditory plus haptic, and 4) visual plus auditory plus haptic.

Based on previous studies [18], we hypothesized that elder drivers will exhibit lower driving performance than younger drivers, independent of modality combination. Informed by multiple resource theory, we also hypothesized that different combinations of multi-modal feedback would reduce the workload required to process navigation information, and that this would be observed through differences in driving performance and cognitive load. To evaluate these combinations, we implemented a driving simulation test-bed with auditory and visual feedback. We also instrumented a steering wheel with vibrotactile feedback. Thirty-three participants (17 elderly) performed a series of tasks using our simulation with each of the feedback combinations described above. We measured driving performance as well as subjective and objective measures of task workload to compare the effectiveness of the different feedback combinations. We define effectiveness as providing route guidance without decreasing task performance or increasing cognitive load: a more effective guidance system should result in safer driving.

We make two contributions. First, we evaluated the effectiveness and safety benefits of different combinations of multi-modal navigation cues for elder and younger drivers. Second, our mixed-methods assessment approach based on task performance, divided attention and induced workload allowed us to evaluate models for predicting